Infrapopliteal angioplasty for critical limb ischemia: Relation of TransAtlantic InterSociety Consensus class to outcome in 176 limbs

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Objective: **Recent data suggest that percutaneous transluminal angioplasty (PTA) may be appropriate primary therapy for critical limb ischemia (CLI). However, little data are available regarding infrapopliteal angioplasty outcomes based on TransAtlantic InterSociety Consensus (TASC) classification. We report our experience with infrapopliteal angioplasty stratified by TASC lesion classification.**

Methods: **From February 2004 to March 2007, 176 consecutive limbs (163 patients) underwent infrapopliteal angioplasty for CLI. Stents were placed for lesions refractory to PTA or flow-limiting dissections. Patients were stratified by TASC classification and suitability for bypass grafting. Primary outcome was freedom from restenosis, reintervention, or amputation. Primary patency, freedom from secondary restenosis, limb salvage, reintervention by repeat angioplasty or bypass, and survival were determined.**

Results: **Median age was 73 years (range, 39-94 years). Technical success was 93%. Average follow-up was 10 months (range, 1-41 months). At 1 and 2 years, freedom from restenosis, reintervention, or amputation was 39% and 35%, conventional primary patency was 53% and 51%, and freedom from secondary restenosis and reintervention were 63% and 61%, respectively. Limb salvage was 84% at 1, 2, and 3 years. Within 2 years, 15% underwent bypass and 18% underwent repeat infrapopliteal PTA. Postoperative complications occurred in 9% and intraprocedural complications in 10%. The 30-day mortality was 5% (9 of 181). Overall survival was 81%, 65%, and 54% at 1, 2, and 3 years. TASC D classification predicted diminished technical success (75% D vs 100% A, B, and C; $P < .001$), primary restenosis, reintervention, or amputation (hazard ratio [HR], 3.4; 95% confidence interval [CI], 2.1-5.5, $P < .001$), primary patency (HR, 2.2; 95% CI, 1.3-3.9, $P < .004$), secondary restenosis (HR, 3.2; 95% CI, 1.6-6.4, $P = .001$), and limb salvage (HR, 2.6; 95% CI, 1.1-6.3, $P < .05$). Unsuitability for surgical bypass also predicted restenosis, reintervention, or amputation, secondary restenosis, need for repeated angioplasty, and inferior primary patency and limb salvage rates.**

Conclusion: **Infrapopliteal angioplasty is a reasonable primary treatment for CLI patients with TASC A, B, or C lesions. Restenosis, reintervention, or amputation was higher in patients who were unsuitable candidates for bypass; however, an attempt at PTA may be indicated as an alternative to primary amputation. Although restenosis, reintervention, or amputation is high after tibial angioplasty for CLI, excellent limb salvage rates may be obtained with careful follow-up and reinterventions when necessary, including bypass in 15%. (J Vasc Surg 2008;48:128-36.)**

Good technical and clinical results have been obtained with pedal bypass for the treatment of tibial occlusive disease causing limb ischemia.[1] A combination of excellent durability and low mortality make this procedure an attractive option for patients with a threatened extremity. However, significant morbidity can be associated with distal bypass surgery. A mortality rate approximating 2% is typically cited, but some studies have found rates as high as 5% to 12%.[1-7] Moreover, not all patients are suitable candidates for distal bypass surgery. Patients may lack conduit or target, be nonambulatory, have a limited life expectancy, have an extensive soft tissue infection overlying a bypass target, or infrequently have comorbidities that make them an unacceptable risk. In these patients, percutaneous transluminal angioplasty (PTA) may constitute a feasible revascularization method rather than primary amputation.

Recently, the Bypass Versus Angioplasty in Severe Ischemia of the Leg (BASIL) study suggested that if the anatomy is conducive for angioplasty, primary PTA might be an appropriate first therapy even if the patient is a good candidate for bypass. Ideal anatomy was not well defined in BASIL, however, and outcomes were not stratified by the distal extent of disease (superficial femoral/popliteal/tibial).[7]

Outcomes of tibial PTA are difficult to predict from the existing literature owing to a lack of details regarding indications for intervention and lesion characteristics.[6-17] The TransAtlantic InterSociety Consensus (TASC) criteria represents a standardized definition for lesion characteristics (Table I).[8,9] Our objective was to review our results of infrapopliteal angioplasty stratifying patients by anatomic characteristics according to the TASC classification.

METHODS

We performed a retrospective study analyzing perioperative and follow-up outcomes of infrapopliteal angioplasty for patients with critical limb ischemia. The study

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Competition of interest: none.

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Table I. TransAtlantic Inter-Society Consensus classification for infrapopliteal lesions[9]

Classification	*Lesion characteristics*
TASC A	Single stenosis <1 cm long
TASC B	Multiple focal stenoses <1 cm long or 1 or 2 stenoses <1 cm involving the trifurcation
TASC C	Stenoses 1 to 4 cm long, occlusion 1 to 2 cm long, or extensive stenosis involving the trifurcation
TASC D	Occlusion >2 cm long or diffusely diseased

TASC, TransAtlantic Inter-Society Consensus.

protocol was approved by the Beth Israel Deaconess Medical Center (BIDMC) Institutional Review Board.

Subjects and setting. All patients who underwent an endovascular procedure performed by a member of the Division of Vascular and Endovascular Surgery at the BIDMC consecutively from February 2004 to March 2007 were recorded in a computerized vascular registry. Demographics, procedural details, and in-hospital outcomes are prospectively recorded in this registry. From this database, we retrospectively reviewed all patients who underwent an attempt at a percutaneous, infrapopliteal angioplasty procedure on a native vessel.

Interventions were performed for critical limb ischemia (CLI), defined as tissue loss, rest pain, or a stenosis in the outflow vessel of a tibial bypass combined with low graft flow velocities that threatened the graft viability. Not included in this review are five interventions that were performed during this time period for disabling claudication in patients who also had concurrent femoropopliteal disease. Preoperative segmental pressures and Doppler waveforms were obtained in all elective cases. In our patients with diabetes, we routinely obtain forefoot pulse volume recordings because of the well-known unreliability of ankle-brachial index (ABI) measurements in these patients. Palpable distal pulses were absent in all patients, and all patients with preoperative vascular studies had dampened forefoot pulse volume recordings.

Most cases were performed in a dedicated angiography suite, initially in a cardiac catheterization laboratory and eventually in an operating room endovascular suite. A few were performed in a standard operating room with a mobile C-arm. Most procedures were performed under conscious sedation; however, general anesthesia was occasionally used for patients unable to adequately lie still.

All patients were anticoagulated with heparin during the procedure to an activating clotting time of 250 to 300 seconds. After the procedure, patients were given a loading dose of clopidogrel and maintained on a 75-mg daily dose for at least 30 days, along with aspirin and statin therapy indefinitely.

Cases were performed using 5F or 6F sheaths preferentially through retrograde contralateral and occasionally through antegrade ipsilateral access. No brachial or other upper extremity access was used. Preference was given to using 0.014- or 0.018-inch guidewire and catheter systems. Angioplasty was performed with noncompliant low-profile balloons. Repeated 2- to 3-minute inflations or cutting balloon angioplasty were performed if significant residual stenosis or flow-limiting dissection was present after a first angioplasty attempt. Subintimal angioplasty was performed for complete occlusions that could not be crossed within the lumen. Stents were placed only for flow-limiting dissections or residual stenosis >30% after primary angioplasty. The type of stent used depended on operator preference and availability. Our current preference is a low-profile self-expanding nitinol stent.

Measurements. We recorded patient demographics, TASC classification, indication, and bypass candidacy status. The primary outcome variable was freedom from restenosis, reintervention, or amputation. Secondary outcomes were technical success, procedural and postoperative complications, conventional primary patency, secondary restenosis, tissue healing, limb salvage, reintervention, and patient survival.

TASC classification was assessed for the individual vessel that underwent intervention. If more than one vessel had a successful intervention, the limb was assigned the worst of the TASC classes for lesions in series (eg, tibioperoneal trunk and posterior tibial) and the lesser class for lesions in parallel (eg, anterior tibial and posterior tibial).

The indication for the procedure was classified as tissue loss (gangrene or nonhealing ulcer) or rest pain. A few patients were treated for the presence of tibial outflow stenosis in the native tibial artery distal to an existing vein graft with low graft velocities. All bypass grafts had initially been placed for either tissue loss or rest pain.

Patients were deemed unsuitable candidates for a bypass procedure if they lacked a bypass target or an adequate vein conduit. A small number of patients had underlying conditions precluding surgery, including severe dementia, significant medical comorbidities, nonambulatory status, or open wounds overlying the only potential bypass target.

Outcome variables. Technical success was defined as a residual stenosis of <30% as assessed on single-view completion angiography. Adjunctive procedures included stent placement, mechanical atherectomy, mechanical thrombectomy, thrombolysis, or intra-arterial nitroglycerin infusion to treat flow-limiting spasm. Concomitant procedures included superficial femoral artery, popliteal, or vein graft angioplasty or stent placement, or both.

Patients were seen for follow-up typically at 2 weeks, then every 3 months for 1 year, and every 6 months thereafter, or more frequently if stenoses were detected or to monitor wound healing. Restenosis and patency were assessed with duplex ultrasound (DUS) analysis of the treated vessel, Doppler waveforms, segmental pressures, pulse volume recordings, and when indicated, angiography. All noninvasive vascular studies were performed in one of two vascular laboratories by a dedicated vascular technician and interpreted by a staff vascular surgeon.

The primary outcome was freedom from tibial restenosis, reintervention, or major amputation. Restenosis was

defined as occlusion or significant stenosis as demonstrated by peak systolic velocity ratio increase of >3.0 on the DUS examination. In our vascular laboratory, this value represents 60% to 80% vessel stenosis and is consistent with reporting standards for prior endovascular series.[10]

Measurement of primary patency followed Society for Vascular Surgery (SVS) reporting standards criteria for patency to allow a more accurate comparison of this series with bypass outcomes.[11] The minimum standard of documented flow by arteriography or DUS was required for a vessel to be considered patent. Treatment failure was defined as any patient who required reinterventions, whether for restenoses or occlusions.

Freedom from secondary restenosis was determined by the last available vascular laboratory study inclusive of patients who had undergone infrapopliteal reintervention by endovascular as well as bypass to maintain or restore flow. The same DUS examination threshold was used for this determination.

Limb salvage was defined as freedom from major amputation (below or above knee). Toe, ray, or transmetatarsal amputations were considered minor amputations. Wound healing or symptom resolution was documented as complete, improved, stable, or worse.

Reintervention included repeat infrapopliteal PTA or bypass graft procedure. Repeat PTA was any attempt at a catheter-based intervention in the tibial lesion(s) previously intervened on. Reintervention by bypass graft was any bypass performed in the ipsilateral limb to an infrapopliteal target encompassing the previously treated area. Survival was assessed using computerized hospital medical records and verified by referencing the Social Security Death Index (http://ssdi.rootsweb.com).

Postoperative complications included any complication that increased length of stay or required blood transfusion, operation, or additional therapy. Intraprocedural complications were those that occurred while in the fluoroscopy suite or operative room and included flow-limiting spasm or thromboembolus. No vessel ruptures occurred in this series.

Statistical analysis. All analyses were performed on a per-limb basis. Preoperative characteristics and outcomes were reported as percentages of the sample. Categoric variables were analyzed by Pearson χ^2 and the Fisher exact test. Median length of stay was compared using the Wilcoxon rank sum test. Treatment outcomes during the course of follow-up were analyzed using Kaplan-Meier methodology, and time-to-failure curves were compared by the log-rank test. Univariate and multivariate Cox regression models were used to assess predictor variables for time-dependent outcomes. Primary restenosis, reintervention, or amputation was assessed both with inclusion and exclusion of technical failures; however, the final reported tables are representative of the entire series as an intention to treat model. Statistical significance was defined as $P < .05$. All statistical tests were done using STATA 8 software (StataCorp, College Station, Tex).

Table II. Demographic data of patients undergoing infrapopliteal angioplasty

Variables	*No. or median*	*% or range*
Age, years	73	39-94
Male	103	59
Comorbidities		
Hypertension	158	90
Diabetes mellitus	126	72
Hyperlipidemia	104	59
Coronary artery disease	106	60
Dialysis-dependant renal failure	29	16
Creatinine >2.0 mg/dL	40	23
Prior myocardial infarction	41	23
Congestive heart failure	55	31
Cerebrovascular disease	36	20
COPD	15	9
Smoker	80	50[a]
Preintervention medications		
Aspirin	118	67
Clopidogrel	55	31
Warfarin	40	23
Statin	88	50
Prior infrapopliteal bypass	47	27
Indication		
Tissue loss	137	76
Rest pain	27	15
Threatened graft	12	7
Not bypass candidate	40	
No bypass target	17	
No bypass conduit	13	
Nonambulatory	3	
Medical contraindication	4	
Wound over potential targets	2	
Severe dementia	1	
TASC classification		
TASC A	41	23
TASC B	38	22
TASC C	46	26
TASC D	51	29

COPD, Chronic obstructive pulmonary disease; *TASC,* TransAtlantic InterSociety Consensus.
[a]Missing values excluded from denominator.

RESULTS

Demographics. Tibial PTA was used to treat 176 limbs in 163 patients. Demographics are summarized in Table II. Median age was 73 years (range, 39-94 years). Most patients were men with hypertension, diabetes, hyperlipidemia, and coronary artery disease. Half of the patients had a history of smoking. Of the 163 patients, 47 (27%) had undergone a prior infrainguinal bypass in the limb intervened on, and 40 (23%) were considered unsuitable candidates for bypass. The lesions that underwent intervention were evenly distributed among the TASC subsets.

Indication for intervention. Most patients were treated for tissue loss, and a lesser number were treated for rest pain (15%) or vein graft outflow stenosis (7%; Table II). More TASC A lesions (8 of 12) were performed for vein graft outflow stenosis than other TASC classifications.

Procedural details. Stents were placed in infrapopliteal vessels in 8% of limbs. Four were placed for flow-

limiting dissections, and the 11 remaining stents were placed for residual stenosis. The stents included six self-expanding stents, six stainless steel balloon expandable stents, and three drug-eluting balloon expandable stents. No significant differences existed among the demographics of patients receiving stents or for outcomes of restenosis, reintervention, or amputation after stenting vs angioplasty only.

Antegrade access was used in 13% of cases. The primary method of intervention was PTA; however, three arthrectomies were performed. Two patients underwent 24-hour thrombolysis of an infrapopliteal vessel, followed by PTA after a stenotic lesion was discovered. A total of 102 patients (58%) had concomitant femoropopliteal angioplasty or stenting, or both. No significant differences were found between groups undergoing single vs multilevel interventions among procedural indications, prior distal bypass grafts, technical success, or restenosis.

Technical success. Technical success was obtained in 163 of 176 limbs (93%). TASC class predicted technical success, with the only technical failures occurring in TASC D lesions (100% for TASC A to C vs 75% for TASC D; $P <$ .0001). Of the 13 technical failures, eight had secondary interventions, one had immediate amputation, and four had no further interventions. Of the eight secondary interventions, five underwent immediate bypass and four had tibial PTA (1 after bypass failure). Amputation was ultimately required in one of the bypass patients and in two of the repeat tibial PTA patients. The remaining reinterventions remained patent at last follow-up. Of the four patients in whom no further procedure was performed, one died at home ≤1 month and two continue to receive wound care for stable wounds. The remaining patient had a concurrent angioplasty in the superficial femoral and popliteal arteries and a toe amputation healed. Technical outcome was independent of stent placement, multilevel interventions, and adjunctive procedures.

Intraprocedural complications. Procedural complications occurred in 10%: flow-limiting spasm (n = 9), vessel perforation (n = 1), and thromboembolus (n = 8). The difference in the rate of complications among TASC classes was not significant ($P = .284$). In addition, no significant difference was found in the number of intraprocedural complications based on the preoperative use of aspirin ($P = .602$) or clopidogrel ($P = .282$). All complications were successfully treated using repeated PTA alone in 4, intra-arterial vasodilators in 6, or rheolytic thrombectomy in 8, or thrombolysis in 9, or both. No patient required emergency surgery, and no potential infrapopliteal bypass targets were compromised.

Perioperative mortality and postoperative complications. Five patients died for an in-hospital mortality of 3%, and four other patients died after discharge ≤30 days from their procedure, for a 30-day mortality of 5%. Two deaths on postprocedure day 1 included a cardiac arrest and an uncontrolled retroperitoneal hemorrhage. The remaining in-hospital deaths occurred >3 weeks in patients who had undergone additional procedures. Two were secondary to septic complications, and one patient sustained a myocardial infarction with acute renal failure. The four out-of-hospital perioperative deaths were from unknown causes.

The postoperative complication rate was 9%. Two pseudoaneurysms were treated with thrombin injection. Five hematomas occurred, one retroperitoneal, one rectus, and three groin (two were surgically evacuated). Congestive heart failure complicated the course of two patients, and myocardial infarctions occurred in two others. Two patients had temporary dysrhythmia, and transient contrast nephropathy developed in four patients.

Length of stay. The median total length of stay was 4 days (range, 0-41 days), whereas the postprocedural length of stay was 2 days (range, 0-38 days). The median length of stay was longer for those intervened on for tissue loss compared with other indications (5 vs 2 days; $P < .0005$). Patients with postoperative complications also had median longer hospitalizations than those without complications (8 vs 3 days; $P < .005$). Discharge destination was home in 75% and to a rehab facility in 25%.

Follow-up outcomes

Freedom from restenosis, reintervention, or amputation. Mean follow-up was 10 months (range, 1-41 months). Freedom from restenosis, reintervention, or amputation was 39% at 1 year and 36% at 2 years (Fig 1, *A*). Freedom from restenosis, reintervention, or amputation at 1 year for TASC A through D was 50%, 39%, 53%, and 14%, respectively ($P < .0001$; Fig 1, *B*). TASC D lesions had a higher restenosis, reintervention, or amputation rate than all others (Fig 1, *C*), even when technical failures are excluded ($P < .005$). Because all technical failures were TASC D, this confirms the significant effect of TASC D regardless of the initial technical success. Freedom from restenosis, reintervention, or amputation at 1 and 2 years for bypass graft candidates (46%, 41%) was higher than for unsuitable bypass candidates (19%, 19%).

TASC D lesions predicted restenosis, reintervention, or amputation whether technical failures were included or excluded: including failures had a hazard ratio (HR) of 3.5 (95% CI, 2.2-5.6, $P < .001$) and excluding failures had a HR of 2.3 (95% CI, 1.3-4.1, $P < .005$). Univariate predictors of restenosis, reintervention, or amputation were TASC D classification and patients who were not candidates for bypass (Table III). The strongest predictor within the bypass candidacy group was a lack of a bypass target vessel (HR, 2.9; 95% CI, 1.6-5.5, $P = .001$). Patients intervened on for graft outflow stenosis had a lower risk. Age, sex, other comorbidities, procedure indication, and multilevel disease were not significant factors. On multivariate analysis, TASC D classification and lack of bypass target remained significant predictors.

A subset analysis excluded all procedures in which multilevel interventions were performed to ensure that this was not a significant factor influencing restenosis. In the 74 patients who underwent intervention for isolated infrapopliteal lesions, freedom from restenosis, reintervention, or amputation at 1 and 2 years was 37%, with a significant

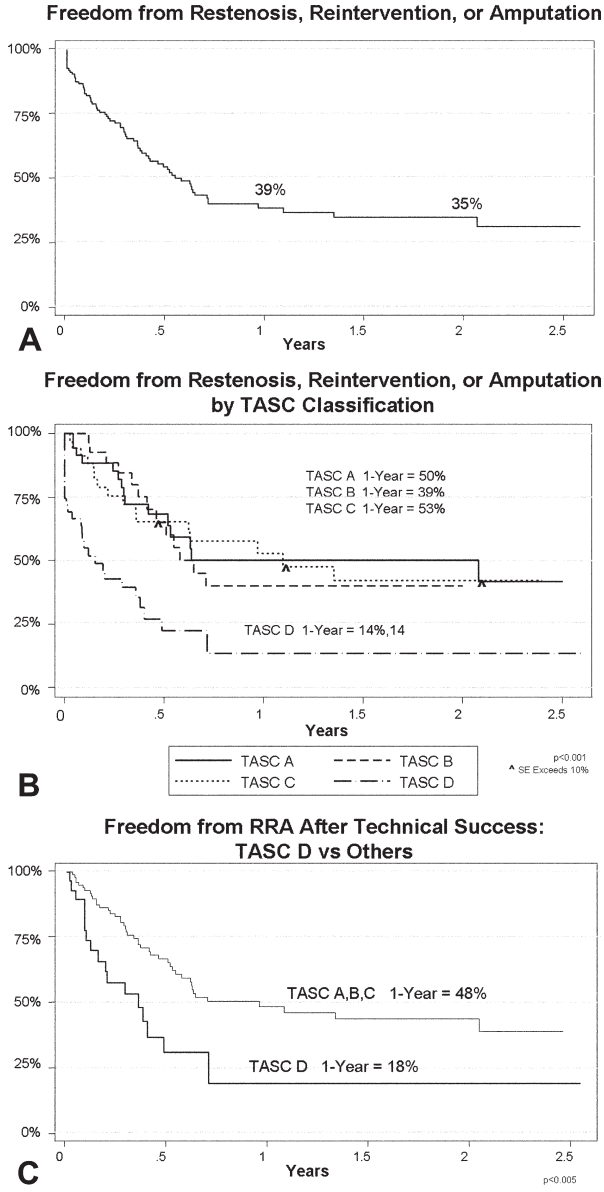

Fig 1. A, The primary freedom from restenosis, reintervention, or amputation at 1 year rises to 42% when technical failures are excluded. The standard error *(SE)* remains <10% throughout. **B,** Freedom from restenosis, reintervention, or amputation by TransAtlantic InterSociety Consensus *(TASC)* classification. A *carat* indicates where SE >10%. The SE remains <10% throughout for the TASC D curve. **C,** Freedom from restenosis, reintervention, or amputation by TASC D, technical success only. The SE remains <10% throughout for both curves.

difference among TASC classes ($P = .007$). This was not significantly different than that of the entire series ($P = .538$). TASC D class and lack of bypass target similarly predicted restenosis, reintervention, or amputation on multivariate analysis (TASC D: HR, 2.5 [95% CI, 1.2-5.2, $P = .015$]; no target: HR, 3.8 [95% CI, 1.4-10.3; $P = .007$]).

Table III. Predictors of restenosis, reintervention, or amputation after infrapopliteal angioplasty

Predictors	*HR*	*95% CI*	P
Univariate			
TASC A	0.6	0.3-1.1	.082
TASC B	0.7	0.4-1.3	.233
TASC C	0.6	0.4-1.1	.091
TASC D	3.5	2.2-5.6	<0.001[a]
Female sex	1.5	0.9-2.3	.109
Hypertension	2.5	0.8-7.9	.124
Hyperlipidemia	1.2	0.8-2.0	.398
Diabetes	1.7	0.9-2.9	.095
Coronary artery disease	1.1	0.7-1.7	.748
Dialysis-dependant renal failure	1.1	0.6-2.1	.704
Creatinine >2.0 mg/dL	0.7	0.4-1.3	.294
Cerebrovascular disease	1.0	0.6-1.7	.940
Smoking	1.1	0.6-1.7	.835
Aspirin	0.9	0.6-1.5	.730
Clopidogrel	1.1	0.7-1.9	.594
Warfarin	1.6	0.9-2.6	.086
Statin	1.1	0.7-1.8	.637
Prior distal bypass	0.9	0.5-1.4	.532
Not bypass candidate—all	2.1	1.3-3.5	.002[a]
No bypass target	2.9	1.6-5.5	.001[a]
No bypass conduit	1.5	0.7-2.8	.299
Other	1.3	0.4-4.0	.703
Indication			
Tissue Loss	1.1	0.6-1.9	.715
Rest pain	1.6	0.9-2.9	.112
Graft outflow stenosis	0.3	0.1-0.97	.043[a]
Multilevel intervention	0.9	0.5-1.4	.541
Stent placement	0.9	0.3-2.3	.760
Procedural complication	1.0	0.5-2.0	.926
Systemic complication	1.2	0.6-2.5	.651
Multivariate			
TASC D	3.4	2.1-5.5	<.001[a]
No bypass target	2.7	1.4-5.0	.003[a]

CI, Confidence interval; *HR,* hazard ratio; *TASC,* TransAtlantic InterSociety Consensus.
[a]Significant value.

Primary patency. Primary patency was 53% and 51% at 1 and 2 years (Fig 2, *A*). Patency at 1 year for TASC A through D was 53%, 58%, 67%, and 37%, respectively ($P < .001$). Multivariate predictors of loss of primary patency were TASC D classification and unsuitable bypass candidacy (Table IV).

Secondary restenosis. Freedom from secondary restenosis was 63% at 1 year and 61% at 2 and 3 years, with a significant difference among TASC classification as well ($P < .001$; Fig 3). Freedom from secondary restenosis for TASC A through D at 1 year was 79%, 82%, 57%, and 43%, respectively. On univariate analysis, secondary restenosis was predicted by TASC D classification, whereas TASC A and B lesions resulted in lower rates. On multivariate analysis, TASC D and lack of bypass target predicted secondary restenosis, but multilevel interventions were protective (Table V).

Limb salvage and wound healing. Mean follow-up assessing wound healing was 12 months (range, 1-43 months). At the last follow-up for those with an indication of tissue loss, wounds were completely healed or improved

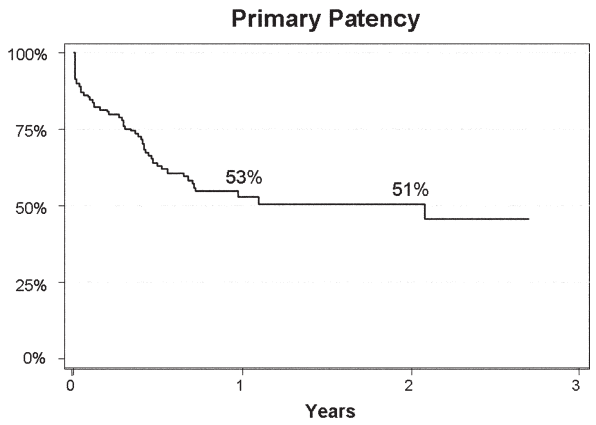

Fig 2. Primary patency rates as determined by conventional criteria. The standard error (SE) remains <10% throughout.

Table IV. Predictors of primary patency, amputation, and reintervention[a] after infrapopliteal angioplasty

Multivariate	*HR*	*95% CI*	P
Primary patency			
TASC D	2.8	1.6-4.7	<.001[b]
Not bypass candidate—all	2.2	1.3-3.9	.004[b]
Amputation			
Not bypass candidate—all	6.3	2.5-15.4	<.001[b]
TASC D	2.6	1.1-6.3	.033
Reintervention PTA			
Not bypass candidate—all	4.6	2.2-9.4	<.001[b]

CI, Confidence interval; *HR,* hazard ratio; *TASC,* TransAtlantic InterSociety Consensus.
[a]There were no significant predictors of reintervention by bypass graft.
[b]Significant.

in 57%, stable in 22%, and worse in 21%. For the 23 patients with an indication of rest pain, improvement was noted in 57%, unchanged symptoms in 22%, and worsening in 17%.

Limb salvage at 1, 2, and 3 years was 84% (Fig 4). A total of 21 amputations were performed ≤1 year, of which 11 occurred at an interval after a second attempt at revascularization (9 angioplasties, 2 bypasses). Additional attempts at revascularization were not considered to be appropriate. Eleven patients going on to amputation had failed bypass grafts before PTA in the leg intervened on. Multivariate predictors of limb loss were TASC D lesions and bypass candidacy status (Table IV).

Survival. Survival was 80%, 63%, and 54% at 1, 2, and 3 years (Fig 5). Unsuitable bypass candidacy status for reasons other than lack of target or conduit was predictive of death (HR, 13.3; 95% CI, 6.4-27.5; $P < .001$). TASC class did not predict survival.

Reintervention. At 1 and 2 years, freedom from bypass was 85%, freedom from repeat infrapopliteal PTA was 74% and 72%, and freedom from either PTA or bypass was 63% and 61% (Fig 6). Three patients had subsequent SFA angioplasties but were noted to have patent tibial vessels at that procedure. On multivariate analysis, noncandidacy for bypass was predictive of reintervention by tibial PTA (Table IV). TASC classification was not predictive of reintervention.

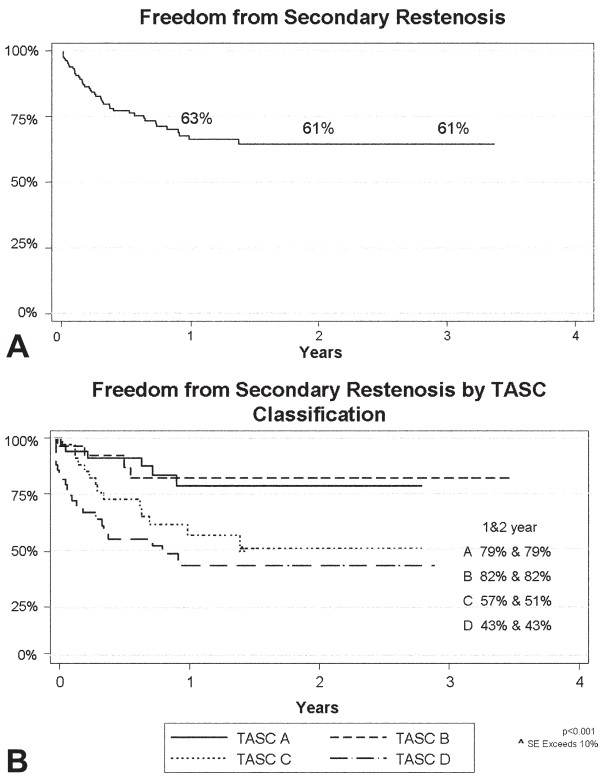

Fig 3. A, Freedom from secondary restenosis. The standard error *(SE)* remains <10% throughout. **B,** Freedom from secondary restenosis by TransAtlantic InterSociety Consensus *(TASC)* classification. The *carat* indicates when the SE >10% for TASC C. The SE remains <10% throughout for all other TASC subgroups.

Table V. Predictors of secondary restenosis after infrapopliteal angioplasty[a]

Predictors	*HR*	*95% CI*	P
Univariate			
TASC A	0.4	0.2-0.9	.027[b]
TASC B	0.3	0.1-0.97	.044[b]
TASC C	1.2	0.7-2.3	.490
TASC D	3.4	1.7-6.7	<.001[b]
Not bypass candidate—all	2.9	1.6-5.2	<.001[b]
No bypass target	5.8	2.9-11.7	<.001[b]
No bypass conduit	0.8	0.3-2.3	.734
Other	2.5	0.8-8.2	.124
Multilevel intervention	0.4	0.2-0.8	.006[b]
Multivariate			
No bypass target	6.1	2.9-12.7	<.001[b]
TASC D	2.8	1.5-5.0	.001[b]
Multilevel intervention	0.4	0.2-0.8	.006[b]

CI, Confidence interval; *HR,* hazard ratio; *TASC,* TransAtlantic InterSociety Consensus.
[a]Comorbidities, indication, stent placement, intraprocedural complications, and systemic complications were non-significant on univariate analysis.
[b]Significant.

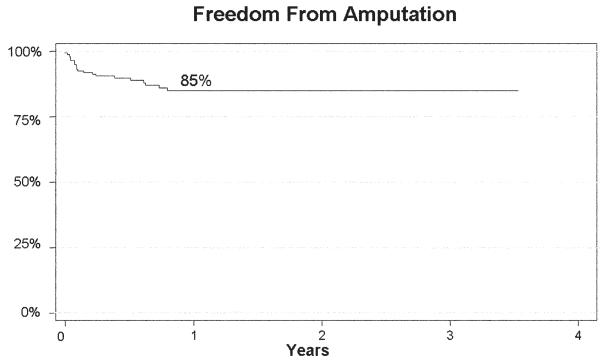

Fig 4. Limb salvage (freedom from amputation). All amputations occurred before 1 year. The standard error remains <10% throughout.

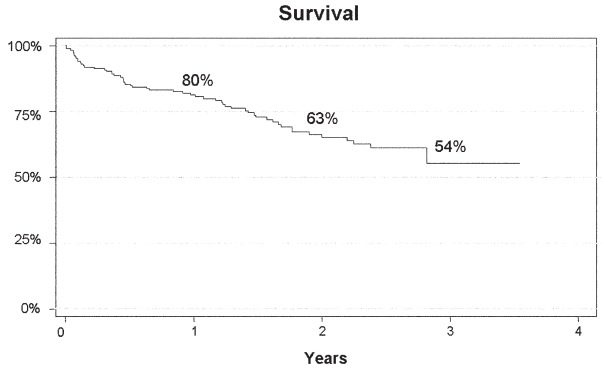

Fig 5. Overall survival. The standard error remains <10% throughout.

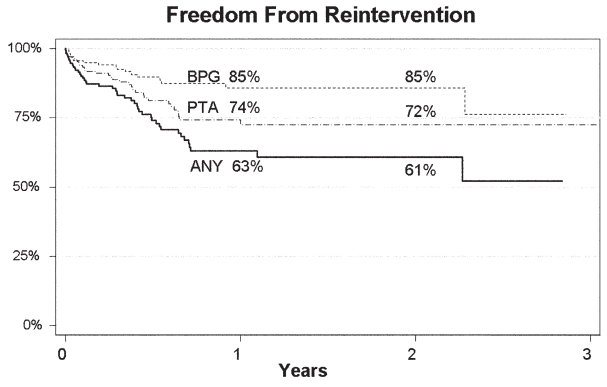

Fig 6. Freedom from reintervention by bypass graft *(BPG)*, repeat infrapopliteal percutaneous transluminal angioplasty *(PTA)*, or either. The standard error remains <10% throughout.

DISCUSSION

This study demonstrates that initial technical success as well as restenosis and limb salvage depends on TASC classification. TASC D lesions fared significantly worse compared with other classifications. Noncandidacy for bypass was also independently predictive of restenosis and amputation, which highlights that the outcomes after distal bypass may not be directly comparable with endovascular interventions. These findings provide strong evidence that TASC class coupled with surgical candidacy is an objective tool that can help to guide clinical decisions.

The decision to report outcomes in the current series as freedom from restenosis, reintervention, or amputation, as well as the traditionally defined primary patency, was made to allow for comparisons not only with endovascular literature but also with bypass series. Results reported within endovascular series vary significantly; however, the term "primary patency" in reference to percutaneous interventions is often used to refer to freedom from restenosis rather than freedom from occlusion or reintervention, as is more commonly reported in bypass literature.

In addition to the variability in follow-up measurements, endovascular reports also lack uniformity in regard to procedural indication, segmental and multilevel disease, and lesion characteristics, making broad conclusions difficult.[10,12-25] A recent analysis by Kudo et al[10] of aortoiliac, femoropopliteal, and infrapopliteal interventions for CLI and also found TASC D lesions to have an adverse impact on restenosis.[10] Their series included 52 infrapopliteal PTAs with a 3-year freedom from restenosis of 24% ± 11%. The effect of TASC class was not analyzed specifically within the infrapopliteal subset, however. Haider et al[12] reported a 1-year freedom from occlusion or reintervention of 67% in 32 limbs undergoing infrapopliteal PTA. They modified the TASC score to reflect the worst TASC lesion of the treated limb, but not necessarily the TASC of the treated vessel. All lesions except one in the infrapopliteal cohort were classified as TASC D. Limb salvage at 1 year was 82%, but restenosis was not reported as an outcome.

Earlier reports have even greater variability in outcomes with less objective measurement criteria to assess restenosis or occlusion. In 1996 Lofberg et al[13] reported 86 infrapopliteal interventions for CLI, defining clinical success as symptomatic improvement and an increase in ABI of >0.1. Rates for 1-, 2-, and 3-year clinical success were 51%, 36%, and 36%, respectively, and 3-year limb salvage was 72%.[13] Dorros et al[14] reported a large series of 215 patients who had undergone tibial PTA for rest pain or tissue loss and found that bypass surgery occurred in 8% and amputation in 9%. Proximal interventions were performed in 59%. Lesions were described as stenotic (71%) or occlusive (29%) but were not characterized further. Unfortunately, no outcomes were reported for restenosis, occlusion, or repeat PTA.[14]

Faglia et al[15] reported a series of 221 angioplasties for ischemic diabetic foot ulcers, of which 42% were performed only in infrapopliteal arteries, 6% in femoropopliteal arteries, and 52% in both levels. A clinical recurrence (pain or worsening ulcer) occurred in 7.3%, and 5% had repeat PTA. Average time to recurrence was 4.6 months, and 5% underwent major amputation. Follow-up ABI and DUS evaluation were only performed in cases of clinical recurrence.[15]

Lastly, a meta-analysis by Kandarpa et al[16] included outcomes of infrapopliteal PTA done in 1282 limbs. Procedural indication was CLI in 86% and claudication in 14%. Primary patency was 79% at 1 year and 74% at 2 years; however, patency definitions were not delineated. Limb salvage at 2 years was 74%.[16]

Although our current series has a low freedom from restenosis, reintervention, or amputation of 39%, primary patency is 53%, and freedom from secondary restenosis is 63%. This approaches bypass outcomes even though nearly one-quarter of the patients were unsuitable candidates for bypass. The Edifoligide for the Prevention of Infrainguinal Vein Graft Failure (PREVENT III) trial of bypass grafts performed for critical limb ischemia reported a trial outcome analogous to our measure of restenosis, reintervention, or amputation, defined by PREVENT III as freedom from clinically significant graft stenosis, reintervention, or amputation. The two study arms had a 1-year outcome of 44% and 46% compared with 39% in our series. The 1-year primary patency in that trial was 61%, highlighting the discrepancy of patency measurement methods reported in bypass vs endovascular series. Moreover, the 1-year limb salvage rate of 84% in our series compares favorably with the 88% rate in PREVENT III.[26] These similarities with bypass outcomes show that with diligent follow-up and aggressive reintervention, including bypass in 15% of patients at 2 years, limb salvage can be maintained.

A relatively high postoperative complication and 30-day mortality rate coupled with the 1- and 3-year survival rates seen in this study of 80% and 54% are an indicator of the overall burden of illness that these patients carry.[27] Patients who preferentially undergo a percutaneous intervention tend to be sicker than patients in whom bypasses are the first line of treatment. The long length of stay and need for additional postdischarge services for a procedure that could be performed with an overnight stay indicate other factors necessitating hospital care are often present.

An attempt at percutaneous intervention may be performed as a "salvage" procedure in patients who have limited life expectancies and extensive comorbidities who would have otherwise undergone a primary amputation, which is associated with perioperative mortality rates of 5% to 17%.[28,29] In our study, only two deaths occurred with a close temporal relationship to the percutaneous procedure; nonetheless, the 30-day mortality of 5% was still higher than the 1.7% to 2.4% seen in other infrapopliteal angioplasty series.[13,30] It is difficult, however, to attribute these perioperative deaths directly to the intervention rather than overall illness severity. The pedal bypass series at our institution reported a 30-day mortality of 0.9%.[1] The same series had a 2-year mortality rate of 25% vs the 37% seen here. Other distal bypass series have reported 30-day mortality rates of 2.1% to 5%.[5,7]

This study also reports an overall intraprocedural complication rate of 10%, which is not low. After noting high thrombotic and spasm rates in the early phases of this series, we increased the goal procedural ACT to >300 and began routine use of intra-arterial vasodilators before PTA. We also take care to visualize the wire tip during catheter exchanges to prevent distal migration. Although thrombotic complications may be related to lack of preoperative dual antiplatelet therapy rather than systemic anticoagulation, we noted only one thromboembolic complication in the second half of our series. In addition, arterial spasm would not be affected by antiplatelet therapy.

The choice between PTA and surgery is made at the time of arteriography, without a separate diagnostic arteriogram. We prefer not to operate on patients who are taking clopidogrel, and because most of our cases involve tissue loss, we prefer not to delay surgery; therefore, we do not initiate clopidogrel before arteriography. Technical failure, intraprocedural complications, and restenosis were found to be unrelated to daily preoperative aspirin or clopidogrel use on analysis. All intraprocedural complications were managed in an endovascular fashion. No patient required emergency surgery to correct a procedural complication.

Although the minimally invasive nature of infrapopliteal PTA has obvious appeal, it also has potential disadvantages. These may include conversion of an elective to emergency procedure, loss of bypass targets, a less durable solution, lengthy procedures causing excessive radiation exposure, and the potential for rising costs of care if multiple interventions are necessary. The delay to surgery caused by an inadequate or failed intervention could cause increased ischemia and lead to worsening wounds, minor amputations, and even limb loss, despite the ability to construct a durable bypass graft.

This study has several limitations. It is a retrospective analysis and thus is vulnerable to the bias inherent in that study design. The patient cohort was not homogenous, because many were not considered candidates for bypass. Candidacy for bypass is often subjective and based on a variety of clinical factors. Redo bypasses requiring multiple segments of vein in patients with poor cardiac function and limited mobility may be technically possible but are not an appealing option. Initially, we chose to seek a percutaneous intervention only in patients who were not optimal candidates for bypass. With experience we began treating a broader range of patients.

CONCLUSIONS

This study demonstrates that technical success, freedom from restenosis, reintervention, or amputation, patency, secondary restenosis, and limb salvage with infrapopliteal PTA can be predicted by TASC class and surgical bypass candidacy. Although high rates of restenosis occur, with careful follow-up and reintervention with either repeat PTA or bypass, secondary restenosis and limb salvage comparable with bypass can be achieved. This procedure may be an appropriate alternative for the patient who is not an optimal candidate for bypass and may also be a reasonable first-line treatment for TASC A, B, and C lesions in those patients who are good bypass candidates. Additional long-

term follow-up and cost data are needed to thoroughly define the appropriate role for infrapopliteal PTA.

AUTHOR CONTRIBUTIONS

Conception and design: MS, SB, AH, FP
Analysis and interpretation: SB, KG, HP
Data collection: SB, KG, HP
Writing the article: KG, SB
Critical revision of the article: MS, FP, AH
Final approval of the article: MS, KG, AH, FP
Statistical analysis: KG, MS, SB
Obtained funding: FP, AH, MS
Overall responsibility: MS

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